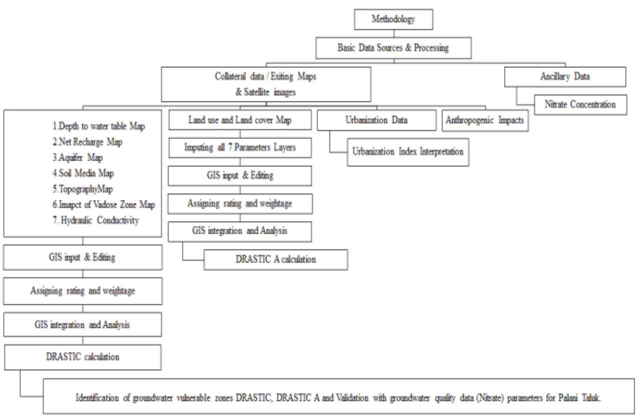
Global NEST Journal, Vol 25, No 3, pp 153-163

Groundwater vulnerability assessment phenomenon using drastic & modified drastic modeling validated with nitrate concentration

Shanmuharajan M.B.[1,2,*], Aparna S.B[3] and Vivek.S[4]
[1]Department of Civil Engineering, College of Engineering and Technology, SRM IST, Kattankulathur, Chennai, India
[2]Department of Civil Engineering, Jaya Engineering College, Chennai, India
[3]Department of Civil Engineering, College of Engineering and Technology, SRM IST, Kattankulathur, Chennai, India
[4]Department of Civil Engineering, Hindusthan College of Engineering & Technology, Coimbatore, India
Received: 29/11/2022, Accepted: 06/01/2023, Available online: 10/01/2023
*to whom all correspondence should be addressed: e-mail: creatorshanmu@gmail.com
https://doi.org/10.30955/gnj.004601

Graphical abstract



Abstract

Urbanized areas groundwater vulnerability and contamination are serious issues that require due attention. There are other models, notably the DRASTIC models employed to assess the vulnerability of groundwater. In a modified version of the DRASTIC model known as anthropogenic influence was incorporated into DRASTICA as a model parameter. The research used a cutting-edge methodology to define the anthropogenic employing satellite data of nighttime lighting to have an impact using human settlements as a stand-in and the Palani Taluk's surrounding land use/landcover. The spatial integration of various parameter maps was done using a geographic information system. According to data on groundwater vulnerability to pollution, around 29.98% of the area is in a very high vulnerability zone, followed by 23.68% of area covers high vulnerability, 25.18% comes under the range of moderate vulnerability, 12.14% covers the area in the zones of low vulnerability, and 8.97% area covers the total area in the ranges of very low vulnerability. Utilizing the amount of nitrate in ground water, the findings were confirmed. It was determined that in an urban environment, the suggested DRASTICA model achieved enhanced than the conservative DRASTIC model. The classifications are as follows: extremely high, high, medium, and low. Very high Vulnerability zones account for 214 values in Palani taluk, the research region, whereas very low vulnerability zones account for 3 values in Palani taluk. Urbanization index showed that anthropogenic impact and the depth of the water table had a substantial impact on groundwater susceptibility to contamination, indicating that manmade effect must be carefully taken into consideration in such studies. This study's modified-DRASTIC/DRASTICA model will aid in better classifying groundwater sensitive areas to contamination where manmade pollution is high, especially in and near metropolitan centers. The groundwater susceptibility possible map that is produced can be more successfully used as the main tool for managing, organizing, and safeguarding groundwater resources. Low nitrate concentrations are found in forests and arid terrain, whereas high nitrate values are found in urban areas. The majority of the Palani taluk has low to moderate nitrate concentrations. The Melkaraipatty and Thalaiyuthu Palani Taluk's urban areas are considered by high sensitivity because of low water levels and strong manmade effect.

Keywords. DRASTICA, groundwater pollution, water quality, anthropogenic activity, etc.

1. Introduction

Quantity and quality of groundwater are significant global issues. Groundwater quality and quantity rapidly declined as a result of rapid development (Shirazi *et al*., 2013; Roy *et al*, 2022).The phrase groundwater vulnerability refers to the natural ground features that control how easily groundwater may be contaminated by human activity (Adamat *et al*, 2003). Since it became clear that ground water needed to be protected from contamination, researchers have made strides in comprehending how susceptible ground water is to contamination (Anew model). However, there are significant ambiguities with the vulnerability assessment techniques that are currently in use (Aller *et al*, 1987).Application of pesticides and fertilizers to the land, animal waste from cattle and other animals, landfills, mining operations, and unintentional releases like chemical spills or storage tank leaks are stressors that have an impact on ground water quality (Alwathaf *et al*, 2011).

Groundwater is one of the most priceless natural resources on the planet, and it indirectly affects people's health and economic development (Barber C *et al*, 1993). It has become a significant and dependable source of water supplies in all climatic areas, serving both urban and rural areas in developed and developing nations due to its many inherent qualities such as Consistent temperature, widespread and continuous availability, excellent natural quality, limited exposure, low development cost, and drought reliability (Todd and Mays, 2005). Groundwater makes up around 22% of the estimated 37M km^3 of freshwater in the land, or about 97% of all the liquid freshwater that may be used by humans (Foster, 1998).

There is a significant water shortage problem in Palani Taluk, Dindigul District, Tamil Nadu, India for agriculture, industry, and domestic uses (Central Pollution Control Board, 2007). The monsoon season in recent years has been unpredictably unpredictable, making it impossible to guarantee surface water supply in the needed quantity at the required time (Chakraborty, 2007; Roy *et al*, 2021). The majority of the Palani Taluk's land is therefore dependent on groundwater, which is obtained by tube wells and digging wells (Evans BM, 1990). However, excessive groundwater pumping in some sections of the review zone has resulted in a decline in groundwater levels (Farzad *et al*, 2012; Easwer *et al*, 2022). Buried wells and hand pumps also dried up over the summer, which led to a worsening of Palani Taluk's chronic water shortage (Hasiniaina *et al*, 2010). The groundwater quality study by Sundararaj *et al*, 2022 was discussed about the quality of groundwater in the same district of the study region and concluded poor groundwater quality in half of the study region by analysis physico chemical parameter.

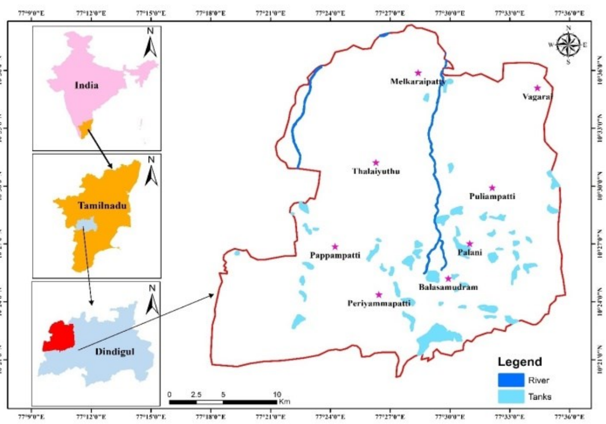


Figure 1. The Location map for Palani taluk region

The DRASTIC model takes into account the primary hydrogeological aspects that could have an effect on aquifer pollution. Its initials stand for D - groundwater depth, R - recharge rate, A - aquifer, S - soil, T - topography, I -impact of the vadose zone, and C - hydraulic conductivity of the aquifer (Huan *et al*, 2012). The sum of the ratings and weights given to each of the parameters results in the DRASTIC Vulnerability Index (DVI) (Environ *et al*, 2010). We were able to identify three classifications, ranging from very low to very high, by examining the vulnerability map (Khodapanah *et al*, 2011).The variety of papers reviewed above assessed groundwater vulnerability without using anthropogenic effects as a DRASTIC model element (Napolitano *et al*, 1996). Anthropogenic factors are a significant factor in groundwater contamination in urban areas (National Research Council 1993). The type of aquifer and the availability of data influenced the model selection. The National Water Well Association (NWWA) and the US Environmental Protection Agency (EPA) collaborated to develop the DRASTIC model to investigate groundwater contamination vulnerability (Aller *et al*., 1987; Sivakumar *et al*, 2022).

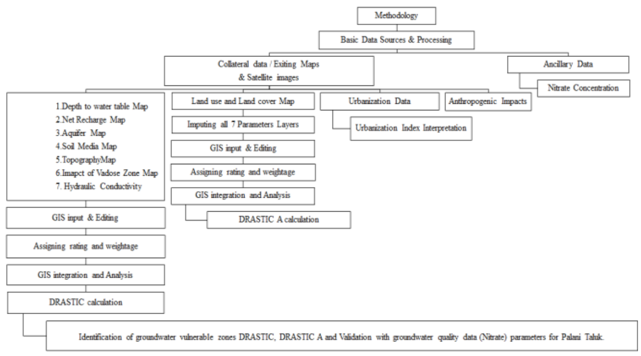


Figure 2. Methodology flow chart for Palani taluk region

The current study presented an altered DRASTIC model, also known as DRASTICA, in which the letter "A" stands for a new parameter known as effect of anthropogenic activities. The land use parameter was employed in a modified DRASTIC model by numerous additional researchers, including (Secunda *et al*., 1998; Adamat *et al*., 2003); Huan *et al*., 2012). Additionally, the new thing in this research is we compared nitrate concentration with DRASTICA results to validate the results of the anlysis. By combining anthropogenic factors with satellite data as a proxy, we were able to successfully recognize groundwater sensitive zones in the research region of Palani Taluk.

2. Study area

The study area zone covers a 766.83 km^2 area with latitudes between 10°20'2" and 10°38'24" N and longitudes between 77°18'6" and 77°35'41" E. From which 116.85 km2 of hilly landforms are made up. The location map of Palani taluk in Figure 1. The subject of the review is Dindigul region of Tamil Nadu. Precipitation in the south-west is a major source of groundwater season. For 33 years, the usual average rainfall is 690 mm (1980 – 2013). The major soil types of the study area namely Clayey Soil, Cracking Clay Soil, Gravelly Loam Soil, and Loamy Soil and the lithology of the area mainly consisted by Charnockite, Granite, Garnet, Granolite, and Hornblende-Biotite Gneiss.

3. Materials and methodology

The specific data types and sources used to create the input parameter maps (layers) for the DRASTIC model. Using ArcGIS (version 9.3) software, input dataset preparation and DRASTIC model implementation were completed. Figure 2 depicts the plan of the dispensation strategy used in the work.

3.1. Assessment of groundwater vulnerability to pollution

The US Environmental Protection Agency developed the DRASTIC model, which is one of the most used techniques for evaluating the vulnerability of groundwater to contamination, according to Aller *et al*. (1987). The areas that were more susceptible to pollution or groundwater vulnerability were identified using this approach. Planning, groundwater management, and groundwater protection can all benefit greatly from the groundwater vulnerability maps (Rosen, 1994). The following seven key hydrogeological and terrain factors are included in the model; they control the occurrence and transport of groundwater into the system. The ability of a pollutant to travel from the earth's surface to an active aquifer is measured by groundwater vulnerability (Rahman, 2008). The vulnerability studies can provide invaluable information about stakeholders working to stop further environmental deterioration (Mendoza and Barmen, 2006)

Depth to water level (D), Recharge (R), Aquifer media (A), Soil media (S), Topography (T), Impact of vadose zone (I), and Hydraulic conductivity (C) (Secunda S *et al*, 1998). These 7 variables were weighted based on their comparative significance to the aquifer's potential for pollution (Table 1). Depending on their relation significance to contamination potential, each of these parameters was ranked (or referred to as ratings) and divided into various ranges and classes (Table 2). The following equation was used to calculate the DRASTIC Index: (Shirazi SM, 2013)

$$\text{DRASTIC INDEX} = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w \quad (1)$$

where, respectively, r and w were the ratings and weights given to each parameter. The risk of groundwater pollution increases with the DRASTIC Index value.

Table 1. Weight assigned for seven parameters

SI.NO	Drastic Parameters	Weights
1	Depth to water table	5
2	Net Recharge	4
3	Aquifer media	3
4	Soil media	2
5	Topography	1
6	Impact of vadose zone	5
7	Hydraulic Conductivity	3

4. Results and discussions

Utilising DRASTIC, DRASTIC Modified, or DRASTICA techniques, seven and eight thematic maps were created for the study area's aquifer vulnerability assessment. The following are the subsequent steps.

4.1. Depth to water table

The distance from the land surface to the water table, or depth to water table, is a key factor in determining how susceptible a region is to contamination. Deep water tables typically give contaminated infiltrating waters sufficient time to come into contact with the earth, allowing attenuation processes to remove contamination. Therefore, when determining the vulnerability using the DRASTIC method, the depth to groundwater was given the maximum weight of (5). (Table 1). After collecting the water level data from the Public Works Department, the depth to water table map was made. Figure 3 shows the depth to water table map has four rating categories (3, 3 - 5, 5 - 10, >10).The majority of the Palani taluk regions are covered by between 5 - 10 and 3 - 5 (m) ranges according to the Depth to water table.

4.2. Net recharge

It is the term used to describe how much water percolates through the soil per square inch. Also it is a vital factor in the movement of the pollutants into the groundwater. The ratio of recharge to pollutant transfer is direct. According to the Public Work Department's (PWD) block-by-block net recharge analysis, the study area's net recharge ranged from 55 to 350 mm. As stated by the recharge was given a weight of (4) using the DRASTIC methodology. Reclassification of the recharge layer was done in accordance with the net recharge layer's DRASTIC ratings. Figure 4 shows the final depth to water table map has six rating categories (55 – 100, 100 – 150, 150 – 200, 200 – 250, 250 – 300 and 300 – 350 mm) The majority of the Palani taluk regions are covered by between 250 - 300 (mm) according to the Net Recharge. The recharge was computed using the formula for ground water fluctuation given below.

Table 2. DRASTIC parameters classes and ratings for Palani taluk region (*-Indicating the multiplication of rank and weight)

Parameters	Range	Rating	Weight	Total Weights Rating* Weight
Depth to Water Table (m)	< 3	10	5	50
	3 - 5	9		45
	5-10	8		40
	> 10	7		35
Net Recharge (mm)	55 - 100	5	4	20
	100 - 150	6		24
	150 - 200	7		28
	200 - 250	8		32
	250 - 300	9		36
	300 - 350	10		40
Aquifer media	Charnockite	5	3	15
	Granite, Garnet Granolite	8		24
	Hornblende-Biotite Gneiss	7		21
Soil media	Cracking Clay soil	8	2	16
	Gravelly Loam Soil	7		14
	Clayey Soil	6		12
	Loamy Soil	9		18
Topography(Degree of Slope)	0 – 15	10	1	10
	15 – 30	9		9
	30 – 50	8		8
	50 – 75	7		7
	75 – 89	6		6
Impact of vadose zone	Loamy Sand	5	5	25
	Sandy Clay	7		35
	Silty Clay	3		15
Hydraulic Conductivity (m/day)	1.5 - 3	1	3	3
	3 - 5	2		6
	5 - 8	3		9
	8 - 12	4		12
	12 - 15	5		15

$$R = h \times Sy$$

Where R represents net recharge in metres, h represents the difference in water level in metres, and Sy is the percentage of specific yield for an unconfined aquifer.

4.3. Aquifer media

Aquifer mapping is a scientific process that evaluates the quantity, quality, and sustainability of ground water in aquifers using a combination of field and laboratory studies in geology, geophysics, hydrology, and chemistry. Because the aquifer's capacity to diluted contaminants helps control their concentration, the characteristics of the aquifer media determine vulnerability. The consolidated or unconsolidated material that acts as an aquifer is referred to as aquifer media. The rate at which contaminants come into contact with the aquifer is controlled by its media (Aller *et al.*, 1987). The aquifer media map depicts in Figure 5 and it was prepared using borehole data. They are Charnockite, Granite, Garnet, Granolite, and Hornblende-Biotite Gneiss. Hornblende-Biotite Gneiss aquifer media covers the whole Palani taluk region.

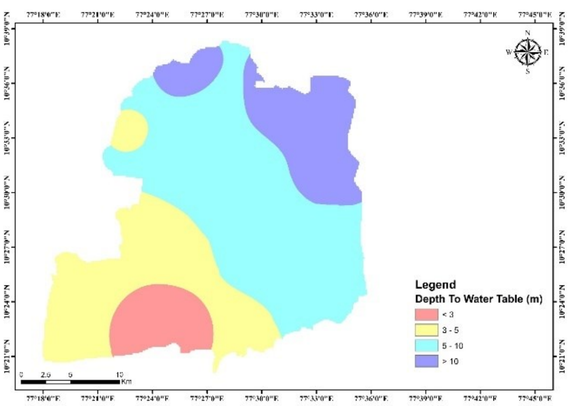


Figure 3. Depth to Water Table Map

4.4. Soil media

The aptitude of pollutants to travel steeply in the vadose zone depends in large part on the amount of recharge that can permeate into the groundwater. Additionally, the attenuation processes of filtration, biodegradation, sorption, and volatilization may be highly substantial where the soil zone is fairly thick. The soil data was used to create a soil map. Clayey Soil, Cracking Clay Soil, Gravelly Loam Soil, and Loamy Soil encircled the entire taluk territory. The soil media map displayed in Figure 6 was created by giving the soil types the appropriate ratings as given in Table 2.

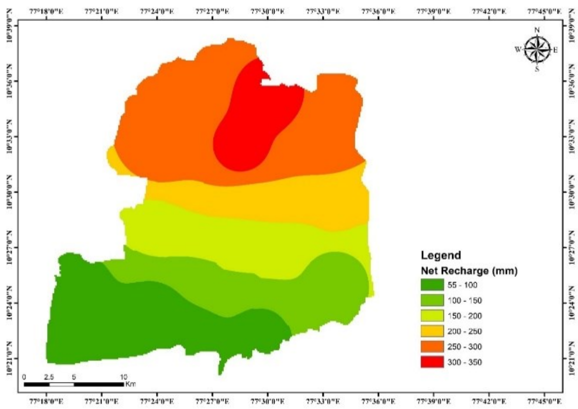


Figure 4. Net Recharge Map

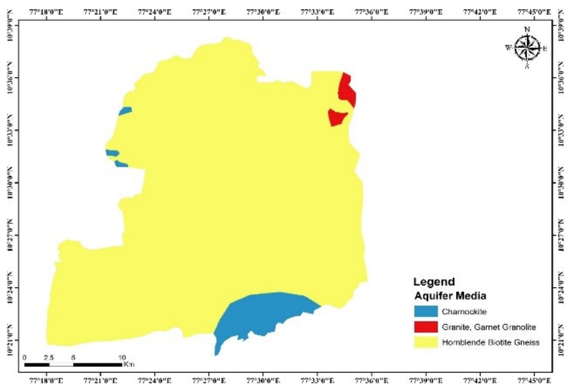


Figure 5. Aquifer Media Map

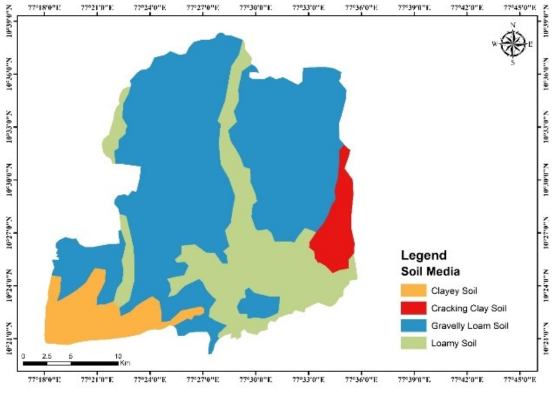


Figure 6. Soil Media Map

4.5. Topography

A slope map is a two-dimensional illustration of a surface's gradient. It displays the slope's current incline, whether it is steep or gentle. You may use slope maps to locate potential dangers, schedule building projects, and more. Topography affects the pace of infiltration by regulating the amount of time that water spends on the soil's surface. Additionally, topography indicates where pollutants are located. The study's digital elevation model was used to determine the topography Figure 7. area. Using the ArcGIS Spatial Analyst Tool, slope with the help of the topographic elevations, values were determined. The ratings of the slope values were made using the standardized classification 5 categories like 0 - 15, 15 - 30, 30 - 50, 50 - 75 and 75 - 89. The most of the Palani taluk was covered by the ranges of 15 - 30 & 30 - 50 values. Slope maps are used to show the relief of the terrain, in contrast to topographic maps, where the altimetry is quantitatively represented with contour lines or with colour bands. The slope numbers, on the other hand, are proportional to the angle (in degrees) of the Earth's surface. Quantitatively, they exhibit the highest relief slope.

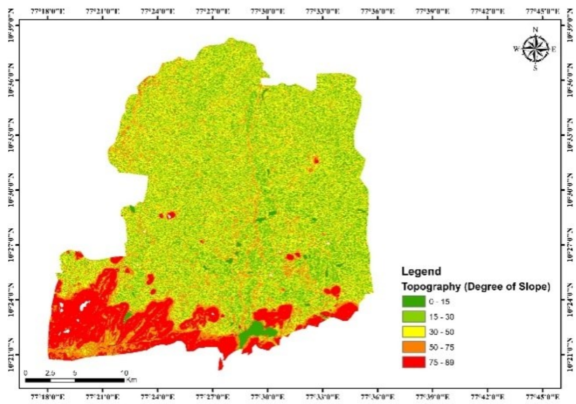


Figure 7. Topography Map

4.6. Impact of vadose zone

The zone above the water table that is unsaturated is known as the vadose zone. The material below the normal soil horizon and above the water table exhibits different attenuation characteristics depending on the type of vadose zone media used. The effect of the vadose zone feature is unit less, and the parameter's variety of standards is determined by the qualitative properties of the vadose zone material. By attenuating contaminants through filtration, chemical reaction, and dispersion mechanisms, this zone significantly reduces groundwater pollution (Shirazi *et al*., 2013). Sandy clay, silty clay, and loamy sand covered the Palani taluk. Sand and loamy clay made up the majority of the Palani taluk. The rating ranges of the characteristics listed in Table 2 were used to create the impact of vadose zone map shows in the Figure 8.

4.7. Hydraulic conductivity

Aquifer materials' hydraulic conductivity is their capacity to convey water. Only the aquifers are included in the hydraulic conductivity data, which is governed by the aquifer's material properties and the quantity of unified void places. Groundwater pollution has a great potential in the high hydraulic conductivity zone (Aller *et al*., 1987). Hydraulic conductivity was computed using data from borehole pumping tests (CGWB 2009). It was found that the study area's hydraulic conductivity ranged from 1.5 to 3, 3 to 5, 5 to 8, and 12 to 15. Figures 9 depict a map of the research area's hydraulic conductivity (m/day). As indicated by the parameters rating ranges in Table 2. Most of all Palani taluk was surrounded by 8 – 12 ranges in the analysis of Hydraulic conductivity.

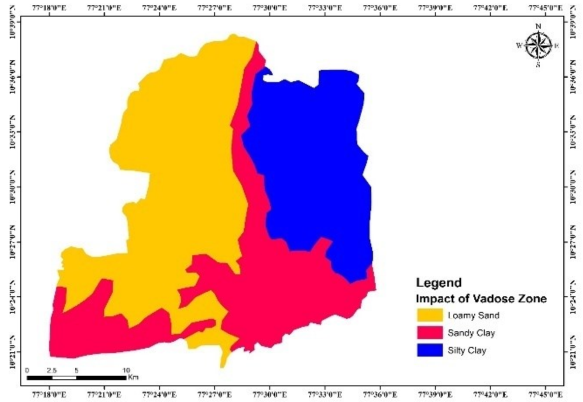


Figure 8. Impact of Vadose Zone map

4.8. DRASTIC model

The DRASTIC model takes into account the primary hydrogeological aspects that could have an influence on aquifer pollution. Groundwater depth is denoted by the letters D, recharge rate by the letters R, aquifer by the letters A, soil by the letters S, topography by the letters T, vadose zone influence by the letters I, and hydraulic conductivity of the aquifer by the letters C. The groundwater vulnerability is assessed using the Drastic index approach and seven different dramatic themed layers are added using Arc GIS's raster calculation tool. The Drastic index values for this research region, which range from 3 to 214, have been reclassified into very low, low, medium, and high according to the new classifications for groundwater contamination, which range from very low to very high. The very high-class accounts for 29.98% of the population, followed by high class (23.68%), medium class (25.18%), low class (12.14%), and very low classes (8.97%). If the research area as a whole is more vulnerable to groundwater contamination. Areas in the research region's north east and south west were identified based on their low hydraulic conductivity and moderate to low risk. North-west and north-south directions are identified in this analysis as having extremely high and high vulnerability. The west and south of the research region are categorised as having low and extremely low groundwater susceptibility due to their higher hydraulic conductivity and groundwater infiltration rate. In addition, the shallowness of the aquifer makes it simple for agricultural pollutants to mix with recharge water and contaminate groundwater. DRASTIC Map shows in the Figure 10. Table 5 shows the DRASTIC Vulnerability analysis for Palani taluk region.

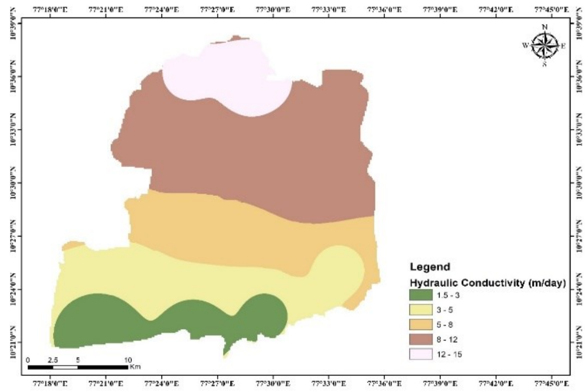


Figure 9. Hydraulic Conductivity map

5. Land Use and Land Cover

The type of LuLc pattern and manmade actions have a substantial impact on the majority of the area's groundwater susceptibility (Periyasamy*et al*, 2021). The Palani taluk Land use and land cover map was show in Figure 11 depicted ten classifications of land: Barren Rocky, Built Up Land, Crop Land, Fallow Land, Forest, Grass Land, Plantation, River, Scrub Land and Tanks. The severity of pollution potential varied depending on the kind of land use, including urban, commercial, agricultural, and industrial. Hydrogeological characteristics can have a big impact on land use parameters. A significant majority of the study region is used for agricultural, according to the land use classification. The second significant portion of the area is made up of adjacent non-agricultural land and urban pavements. The remaining areas are further divided into Barren Rocky, Forest, Grass Land, River, Scrub Land and Tanks. In agricultural areas, groundwater is particularly susceptible to nitrate accumulation. Nitrate distribution in groundwater systems is primarily influenced by soil dynamics, including recharge rate, groundwater movement, and on-ground nitrogen input (Shirazi *et al*., 2013). Palani taluk land use classification showed that agricultural and urban activities had a substantial impact on the research area's groundwater quality. Barren rocky covers 3.93 km², built-up land occupies 24.54 km², crop land occupies 290.17 km², fallow land occupies 163.54 km², forest occupies 42.86 km², grass occupies 86.20 km² and plantations occur on 55.99 km², rivers occupy 2.61 km², scrub land occupies 38.74 km², and tanks occupy 19.13 km². Table 3 shows Land use and land cover classification table for Palani taluk.

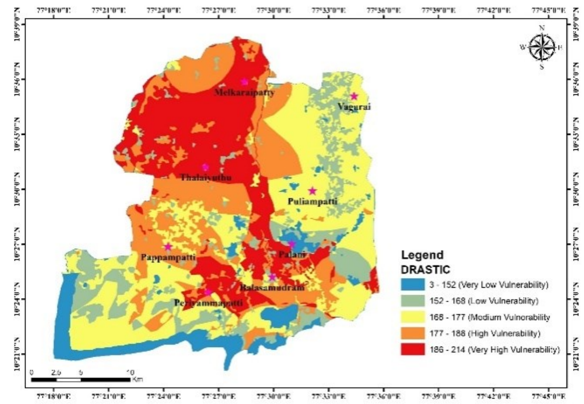


Figure 10. DRASTIC map

6. Urbanization index dataset

The urbanisation index map was produced using a visual interpretation of the urbanisation extraction data from Landsat 8 OLI/TIRS. Using a map of the research area's urbanisation index, the Lu/Lc map was further improved. Based on the urbanisation index map shown in Figure 12, the built-up class of the land use and land cover map for the Palani Taluk was further divided into five classes: built-up with very high density, built-up with very low density, built-up with high density, built-up with low density, and built-up with medium density.

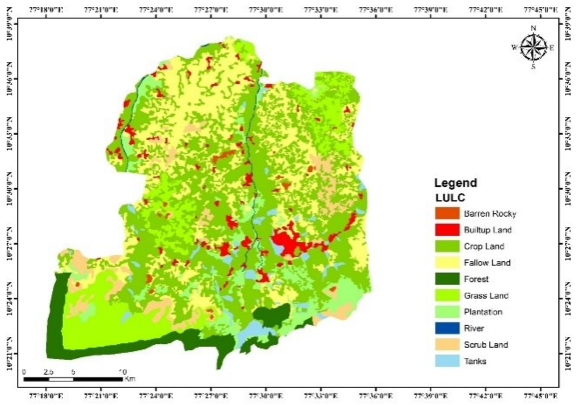


Figure 11. Land use and Land cover map

7. Preparation of anthropogenic impact map

The term human influence on the environment also known as anthropogenic impact describes modifications that humans either directly or indirectly make to biophysical environments, ecosystems, biodiversity, and natural resources. The physical environment is negatively impacted by a variety of human activities including deforestation, pollution, overcrowding, and the combustion of fossil fuels. Changes like this have contributed to climate change, soil erosion, poor air quality, and undrinkable water. The anthropogenic effect map was produced using the Lu/Lc map and the urbanisation index map for the Palani Taluk region. The creation of the anthropogenic impact map for the Palani taluk is depicted in Figure 13.

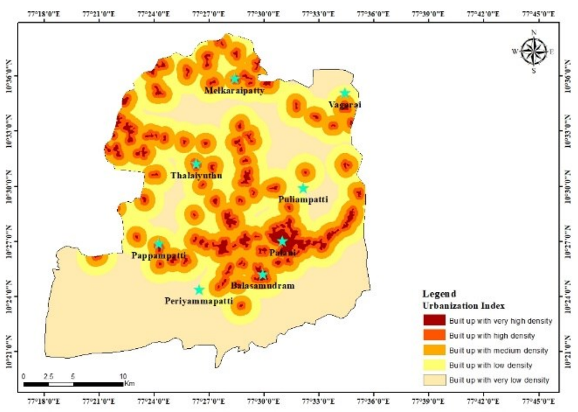


Figure 12. Urbanization Index map

8. Generation of an updated DRASTIC or DRASTICA risk map

After combining with the DRASTIC map, the study evaluated the groundwater susceptibility created on manmade actions. By incorporating anthropogenic effect as an additional element into the standard DRASTIC technique, the DRASTICA risk map was created. The altered DRASTICA method was the name given to this arrangement. Anthropogenic impact map was graded and weighted to create the modified DRASTIC map based on the assumptions of land use classes (Secunda *et al*., 1998; Al Adamat *et al*., 2003; Shirazi *et al*., 2013). The map of anthropogenic effect was converted into a raster grid and multiplied by the parameter's weight (Aw = 5). The manmade effect map was placed over the traditional DRASTIC map in order to provide a spatial correlation between the two maps. The modified DRASTIC Index (MDI), also known as the DRASTICA index, was created by adding the final resultant grid coverage to the conventional DRASTIC Index (DI) according to the following equation (Shirazi *et al*., 2013). Table 4 show Lu/Lc Groups and their allocated scores.

$$\text{MDI or DRASTICA Index} = DI + A_r A_w \qquad (2)$$

where Ar and Aw stand for the anthropogenic impact parameter's rate and weight, respectively. DRASTICA's map identified research area regions and human activity categories that are more likely to affect groundwater vulnerability.

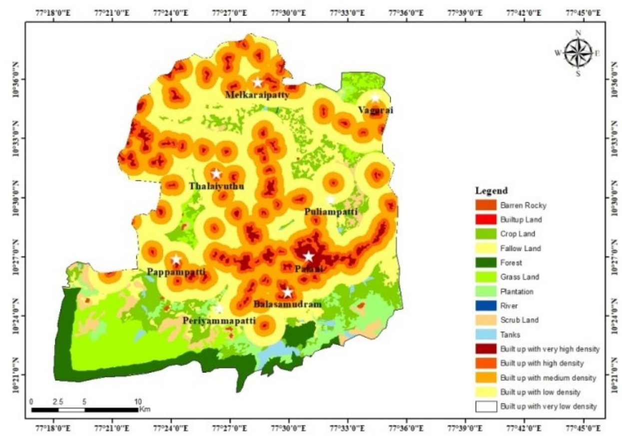


Figure 13. Anthropogenic Impact map for Palani taluk region

Figure 14 of the DRASTICA risk map was arranged into five categories: very low (3–160), Low (161–180), moderate (181–200), high (201-220) and very high (221 – 254) susceptibility. The study's conclusions revealed that 190.85 sq. km of the region are covered in very high highly sensitive zone, which covers 248.45 sq. km are the highly vulnerable zones, 126.8 sq. km are classified as a medium vulnerable zone, and 55.6 sq. km, under 5.6 sq.km are considered low and very low vulnerable zones. DRASTICA's risk map displayed indicates the highly vulnerable areas expanded by over 20% from the moderately vulnerable locations when contrasted to a DRASTIC map (Table 6). In comparison to conservative risk maps, the DRASTICA map depicts a more favourable scenario of vulnerability due to its confirmation by groundwater field data quality. Urban regions have exceptionally high levels of nitrate contamination as a result of human activity.

The resulting groundwater susceptibility map can be used more effectively as a foundational tool for the management, preparation, and defence of groundwater wealth. The Melkaraipatty and Thalaiyuthu due to shallow water levels and significant anthropogenic effect, Palani Taluk's urban areas are characterised by high susceptibility. The majority of the district is included in due to agricultural activities, there is a very high, high, and moderate sensitive zone. The locations near sources of water, forests, shrub land, and Low vulnerability applies to waste land. The city vulnerability of some locations to pollution was great. Groundwater Urban samples also revealed significant nitrate levels concentrations. Table 6 shows the DRASTIC A Vulnerability analysis for Palani taluk region.

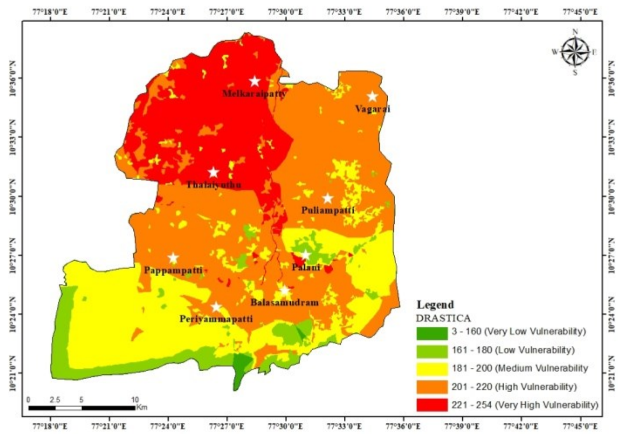


Figure 14. DRASTIC A Vulnerability map for Palani taluk region

Table 3. Land use and land cover classification table for Palani taluk

Type	Area (Sq.km^2)	Percentage (%)
Barren Rocky	3.93	1%
Builtup Land	24.54	3%
Crop Land	290.17	40%
Fallow Land	163.54	23%
Forest	42.86	5%
Grass Land	86.20	12%
Plantation	55.99	8%
River	2.61	2%
Scrub Land	38.74	5%
Tanks	19.13	2%
Total	727.74	100%

Table 4. Land use Classes and their assigned ratings

S.NO	LAND USE	Ratings
1.	Built up with very high density	10
2.	Built up with high density	9
3.	Built up with moderate density	8
4.	Built up with low density	7
5.	Built up with very low density	6
6.	Crop land	8
7.	Plantation	6
8.	Fallow Land	7
9.	River	6
10.	Tanks	9
11.	Scrub Land	6
12.	Grass Land	7
13.	Barren Rocky	3
14.	Forest	2

9. Nitrate Concentration

The nitrate water quality parameter was used to validate both the traditional DRASTIC and DRASTICA methodologies used (Figure 15).Nitrate does not typically occur in nature. Because of this, it occurs in a groundwater system identifies a source of pollutants like, from anthropogenic and agricultural activity. Nitrate (NO_3^-) content in several of the groundwater samples from Palani taluk is found to be higher than the desired limit. Pointing to polluting sources' inputs. Correlations were created using nitrate concentrations use the usual DRASTIC Index (DI) values and DRASTIC Index, amended (MDI). A technique is correlation for inspecting the relationship between two quantifiable and continuous variables (Snedecor, 1900; Pearson, 1900; Cochran, 1980).

High nitrate values are shows in the urban zones and low nitrate concentration are shown in forest and barren lands;

most of the Palani taluk covers low nitrate and moderate nitrate concentration. Figure 15 shows the nitrate concentration map for Palani taluk.The fact that DRASTIC and DRASTIC A have high vulnerability ratings indicates that nitrate concentrations are higher than average, whereas low nitrate concentrations indicate low vulnerability. Melkaraipatty and Thalaiyuthu are responsible for the analysis of the very high sensitivity zones in DRASTIC and DRASTIC A. Pappampatti, Palani, Balasamudram, and Periyammapatti are high vulnerability zones.

10. Conclusions

The study was conducted in Palani taluk, Tamil Nadu, by using the DRASTIC model, an empirical index. Additionally, a modified inventive methodology the development of the DRASTIC model or DRASTICA involved using both the manmade influence and the Satellite measurements of the Lu/Lc adjoining the Palani taluk area and nightlights from human settlements as a proxy. the traditional three classes (low, medium, and high) were displayed on the DRASTIC risk map. Changed DRASTIC or (high susceptibility) Four classes of vulnerability (low, medium, high, and very high vulnerability) were represented by the DRASTICA risk map. The DRASTICA procedure was used. to provide stronger evidence of groundwater vulnerability evaluation in urban settings. With the right tools, the technique can be applied in various metropolitan areas, alterations to hydrogeological setting ratings.

Table 5. DRASTIC Vulnerability analysis for Palani taluk region

S.No	Drastic Index range	Degree of Vulnerability	Area Covered in Sq.km
1	3-152	Very Low Vulnerability	65.3 (8.97 %)
2	152-168	Low Vulnerability	88.4 (12.14 %)
3	168-177	Medium Vulnerability	183.24 (25.18 %)
4	177-186	High Vulnerability	172.35 (23.68 %)
5	186-214	Very High Vulnerability	218.19 (29.98 %)

According to LULC analysis of Palani taluk, Bare rocky land makes up 1% of Palani Taluk, whereas built-up land makes up 3%, crop land makes up 40%, fallow land makes up 23%, forest makes up 5%, grass makes up 12%, plantations make up 8%, rivers make up 2%, scrub land makes up 5%, and tanks make up 2%.In DRASTIC Analysis, outcome of vulnerability zones occupying like very low vulnerability as 8.97%, Low vulnerability as 12.14%, Moderate vulnerability as 25.18%, high vulnerability as 23.68% and very high vulnerability zones covers 29.98%. In DRASTIC an Analysis, outcome of vulnerability zones occupying like very low vulnerability as 1%, Low vulnerability as 7.02%, Moderate vulnerability as 17.44%, high vulnerability as 48.17% and very high vulnerability zones covers 26.13%.

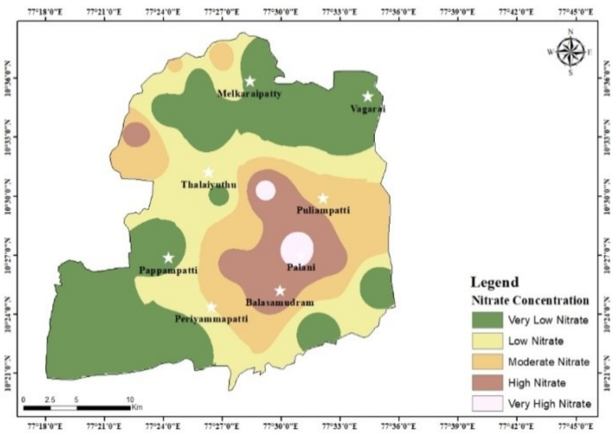


Figure 15. Nitrate Concentration map for Palani taluk

Table 6. DRASTICA Vulnerability analysis for Palani taluk region

S.No	Drastic Index range	Degree of Vulnerability	Area Covered in Sq.km
1	3 – 160	Very Low Vulnerability	5.6 (1 %)
2	161 – 180	Low Vulnerability	55.6 (7.02%)
3	181 – 200	Medium Vulnerability	126.8 (17.44 %)
4	201 - 220	High Vulnerability	248.45 (48.17 %)
5	221 - 254	Very High Vulnerability	190.85 (26.13 %)

For validating the DRASTIC & DRASTIC A implement the Nitrate concentration for Palani taluk region, according to research high vulnerability zones are accumulated in urban or built-up areas, highly concentrated nitrate values are presented in the ground water sample near the same urban and city zones. Hence the values of DRASTIC and DRASTIC A have high vulnerability is means the values of nitrate concentration is more, the nitrate concentration is less meaning the vulnerability is low. The analysis of DRASTIC and DRASTIC A the very high vulnerability zones come under the Melkaraipatty and Thalaiyuthu. High vulnerability zones come Pappampatti, Palani, Balasamudram and Periyammapatti. Moderate zones are covers Puliampaati, Vagarai during DRASTIC analysis. These are all comes under high vulnerability in DRASTIC A analysis. In order to overcome with this groundwater vulnerability proper rehabilitation, maintenance and construction of public tube wells and renovation of dug wells in areas with geogenic contamination should be needed and proper artificial recharge structure need to construct as per the drainage network of the study region.

Abbreviations

DRASTIC - Groundwater **D**epth, **R**echarge rate, **A**quifer media, **S**oil media, **T**opography, **I**mpact of the vadose zone, hydraulic **C**onductivity
NWWA - National Water Well Association
DVI - DRASTIC Vulnerability Index
MDI – Modified Drastic Index
CGWB - Central Ground Water Board
PWD - Public Work Department's
GIS - Geographic Information System

References

Al-Adamat R.A.N., Foster I.D.L., and Baban S.N.J. (2003). Groundwater vulnerability and risk mapping for the basaltic aquifer of the Azraq basin of Jordan using GIS, Remote sensing and DRASTIC. *Applied Geography*, **23**, 303–324

Aller L., Bennet T., Lehr J.H., and Petty R.J. (1987). DRASTIC: a standardized system for evaluating groundwater pollution potential using hydrogeologic settings. *Journal of the Geological Society of India*, **29,** 23–37

Alwathaf Y., and Mansouri B.E. (2011). Assessment of aquifer vulnerability based on GIS and ArcGIS methods: a case study of the Sana’a Basin (Yemen). *Journal of Water Resource and Protection*, **3**(12), 845–855

Alam F., Umar R., Ahmad S., and Dar A.F. (2012). A new model (DRASTICLU) for evaluating groundwater vulnerability in parts of Central Ganga plain, India. *Arabian Journal of Geosciences*, **7**, 927–937

Barber C., Bates L.E., Barron R., and Allison H. (1993). Assessment of the relative vulnerability of groundwater to pollution: a review and background paper for the conference workshop on vulnerability assessment. *Journal of Australian Geology and Geophysics*, **14**(2–3), 1147–1154 Census of India (2011). http://censusindia.gov.in

Central Pollution Control Board (CPCB). (2007). Status of groundwater quality in India-part-I. Ministry of Environment and forest, Groundwater Quality Series: GWQS/ 09/2006–2007

Chakraborty S., Paul P.K., and Sikdar P.K. (2007). Assessing aquifer vulnerability to arsenic pollution using DRASTIC and GIS of North Bengal Plain: a case study of English Bazar Block, Malda District, West Bengal, India. *Journal of Spatial Hydrology*, **7**(1), 101–121

Chandramohan D.R., Kanchanabhan T.E., Siva Vignesh N., and Krishnamoorthy R. (2017). Groundwater fluctuation in Palani Taluk, Dindigul District, Tamilnadu, India.

Easwer V., Kolanuvada S.R., Devarajan T., Moorthy P., Natarajan L., Chokkalingam L., and Roy P.D. (2022). Vulnerability mapping of the Paravanar sub-basin aquifer (Tamil Nadu, India) in SINTACS model for efficient land use planning. *Environmental Research*, **204**, 112069.

Evans B.M., Myers W.L. (1990). A GIS-based approach to evaluate regional ground water pollution with DRASTIC. *Journal of Soil and Water Conservation*, **45**, 242–245.

Farzad B., Shafri H.Z.M., Mohamed T.A. (2012). Groundwater intrinsic vulnerability and riskmapping. Proceedings of the Institution of Civil Engineers, **165**, 441–450

Foster S Groundwater: assessing vulnerability and promoting the protection of a threatened resource. Proceedings of the 8th Stockholm Water Symposium, 10–13 August, Sweden, 1998, pp. 79–90.

Hasiniaina F., Jianwei Z., and Luo G. (2010). Regional assessment of groundwater vulnerability in Tamtsag basin, Mongolia using DRASTIC model. Journal of American Science, **1**(66), 65–78

Huan H., Wang J., Teng Y. (2012). Assessment and validation of groundwater vulnerability to nitrate based on a modified DRASTIC model: a case study in Jilin City of northeast. *Science of the Total Environment* **440**, 14–23

Khan M.M.A., Umar R., Lateh H. (2010). Assessment of aquifer vulnerability in parts of Indo Gangetic plain, India. *International Journal of Physical Sciences*, **5**(11), 1711–1720

Khodapanah L., Sulaiman W.N.A. (2011). Groundwater quality mapping of an alluvial aquifer, Eshtehard, Iran, Pertanika. *Journal of Science and Technology*, **19**, 59–67

Mohammad M.J., Shafee S.K., Rajesh V., Urmila L.J.S., Maheshwari B., and Shirisha H. (2017). Physico-Chemical Parameters Assesment of Ground Water In Urban Area of Khammam, Telangana. *International Journal of Civil Engineering and Technology*, **8**(3), 232–243.

Napolitano P., and Fabbri A.G. (1996). Single-parameter sensitivity analysis for aquifer vulnerability assessment using DRASTIC and SINTACS. In: Proceedings of the Vienna conference on hydrology GIS 96

National Research Council (NRC). (1993). Groundwater vulnerability assessment, contamination potential under conditions of uncertainty. National Academy Press, Washington DC

National Water-Quality Assessment Program (NAWQA). (1999). Improvements to the DRASTIC groundwater vulnerability mapping method. U.S. Department of the Interior, U. S. G. S. Fact sheet FS-066-99

Palanichamy R. (2014). Studying the spatio-temporal trends in space-based gravity observations and exploring the relation with precipitation and biophysical parameters over India. Dissertation, University of Twente

Pearson K. (1900). On the criterion that a given system of deviations from the probable in the case of a correlated system of variables is such that it can be reasonably supposed to have arisen from random sampling. *Philosophical Magazine*, **5**(50), 157–175 (reprinted in K. Pearson (1956), pp 339–357).

Periyasamy R., Roy P.D., Chokkalingam L., Natarajan L., Sundar S., Moorthy P., and Gowrappan M. (2021). Transformation Analysis on Landuse/Land Cover Changes for Two Decades Between 1999 and 2019 CE with Reference to Aquaculture—Nagapattinam Coast, Southeast India. *Journal of the Indian Society of Remote Sensing*, **49**(11), 2831–2845.

Rahman A. (2008). A GIS based model for assessing groundwater vulnerability in shallow aquifer in Aligarh, India. *Applied Geography*, **28**(1), 32–53

Rosen L. (1994). A study of the DRASTIC methodology with emphasis on Swedish conditions. *Ground Water*, **32**(2), 278–285

Roy P.D., Selvam S., Gopinath S., Logesh N., Sánchez-Zavala J.L., and Lakshumanan C. (2022). Geochemical evolution and seasonality of groundwater recharge at water-scarce southeast margin of the Chihuahuan Desert in Mexico. *Environmental Research*, **203**, 111847.

Roy P.D., Selvam S., Venkatramanan S., Logesh N., Lakshumanan C., and Sánchez-Zavala J.L. (2021). Identification of sources and groundwater recharge zones from hydrochemistry and stable isotopes of an agriculture-based paleo-lacustrine basin of drought-prone northeast Mexico. *Geochemistry*, **81**(2), 125742.

Sathish Kumar S. and Ravichandran S. (2011). Groundwater Quality Assessment in Cheyyar Region, *International Journal of ChemTech Research*, **3**(3), 1060–1062.

Satish Kumar S.S., and Asadi S.S. (2017). Vutukuru, Assessment of Heavy Metal Concentration in Ground Water by Using Remote Sensing and GIS, *International Journal of Civil Engineering and Technology*, **8**(4), 1562–1573

Secunda S., Collin M.L., and Melloul A.J. (1998). Groundwater vulnerability assessment using a composite model combining DRASTIC with extensive agricultural land use in Israel's Sharon region. *Journal of Environmental Management*, **54**, 39–57.

Shirazi S.M., Imran H.M., Akib S., Yusop Z., and Harun Z.B. (2013). Groundwater vulnerability assessment in the Melaka State of Malaysia using DRASTIC and GIS techniques. *Environmental Earth Sciences*, **70**, 2293–2304

Sivakumar V., Kumar S., Natarajan L., Roy P.D., and Chokkalingam L. (2022). Vulnerability Assessment of Groundwater in Industrialized Tiruppur Area of South India using GIS-based DRASTIC model. *Journal of the Geological Society of India*, **98**(5), 696–702.

Snedecor G.W, and Cochran W.C. (1980). Correlation. Statistical methods, 6th edn. The Iowa State University Press, Ames, Iowa, USA, 171–198.

Sundararaj P., Madurai Chidambaram S.K., Sivakumar V., and Natarajan L. (2022). Groundwater quality assessment and its suitability for drinking and agricultural purpose, Dindigul taluk, Tamilnadu, India. *Chemical Papers*, **76**(10), 6591–6605.

Todd D.K, and Mays L.W. (2005). Groundwater hydrology. 3rd edition, John Wiley & Sons, NJ, 636.

Voudouris K., Kazakis N., Polemio M., and Kareklas K. (2010). Assessment of intrinsic vulnerability using the DRASTIC Model and GIS in the Kiti aquifer, Cyprus. Eur Water, **30,** 13–24

Janeswar Y., Pathak R.K., and Eliyas K. (2011). Analysis of Water Quality using Physico – chemical parameters Satak Reservoir in Khargone District, M.P, India, *International Research Journal of Environmental Sciences*, **2**(1), 9–11.

Yin L., Zhang E., Wang X., Wenninger J., Dong J., Guo L., and Huang J. (2013). A GIS-based DRASTIC model for assessing groundwater vulnerability in the Ordos Plateau, China. *Environmental Earth Sciences*, **69,** 171–185